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SUBJECT: AMS-02 COPV Damage Control Plan

Introduction

The second Alpha Magnetic Spectrometer (AMS-02) payload has three Composite Overwrap Pressure Vessels (COPVs) used to hold pressurized gas for use by the detector: one containing xenon, one containing carbon dioxide, and one containing helium. Accidental impact loads on the outer surface of the tank have the potential to damage the composite fibers. This type of damage can reduce the tank's overall structural strength and pressure rating but is often difficult to identify without very close specialized inspection. For this reason, both ANSI/AIAA S-081 and KNPR 8715.3 require a damage control plan to be developed to mitigate this hazard. This memo therefore summarizes the damage control procedures developed by the AMS-02 project for these three tanks.

All three tanks were manufactured by Arde' Incorporated of New Jersey. None of the tanks used on AMS-02 were uniquely designs for this payload but were duplicates of previously designed tanks for other space applications. The xenon tank is a duplicate of the tank used in the Plasma Contactor Unit (PCU) and was previously certified and flown to ISS on board the Shuttle. The other two tanks have previously been certified for flight on expendable launch vehicles. Each of the tanks has a certificate of conformance from Arde' documenting that it was built, tested, and inspected per their standard procedures which are compliant with ANSI/AIAA S-081.

The xenon and carbon dioxide tanks are mounted adjacent to each other on the Shuttle aft starboard side of the experiment, as shown in Figure 1. Each tank is surrounded by a thin MLI blanket, while a second blanket containing a layer of betacloth surrounds the entire mounting assembly. In addition, the outside surfaces of both tanks is protected by a rigid MMOD shield. The helium tank is mounted on the lower ring of the AMS-02 Vacuum Case (VC), as shown in Figure 2. It is entirely surrounded by an MMOD shield.

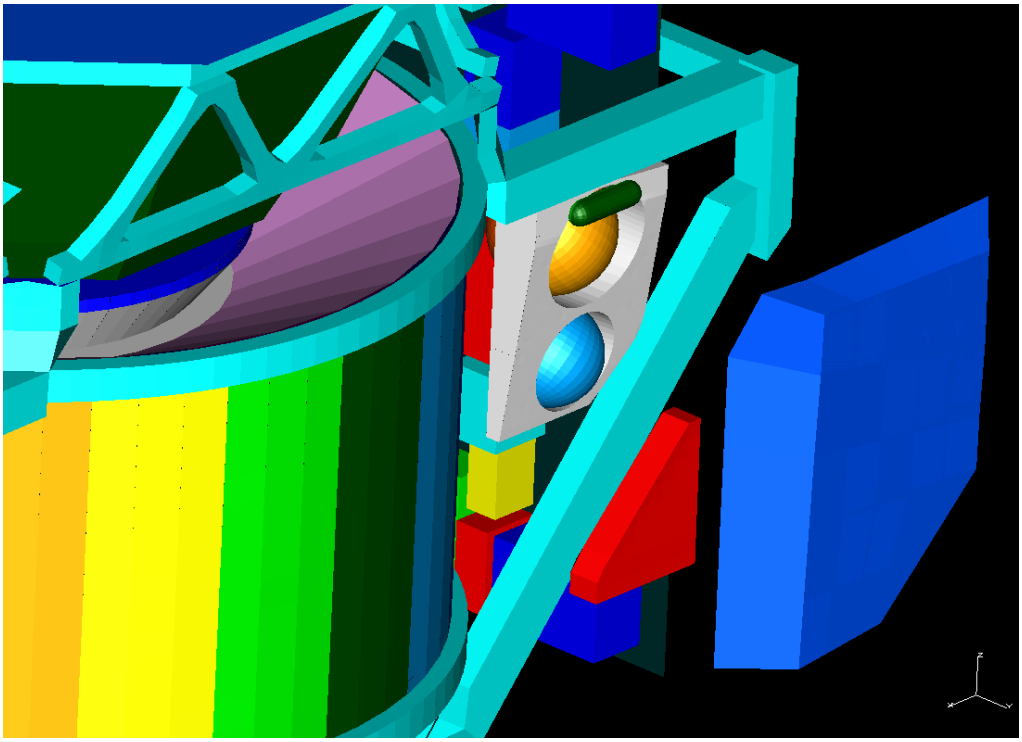

Figure 1: Transition Radiation Detector (TRD) Gas Supply Tanks

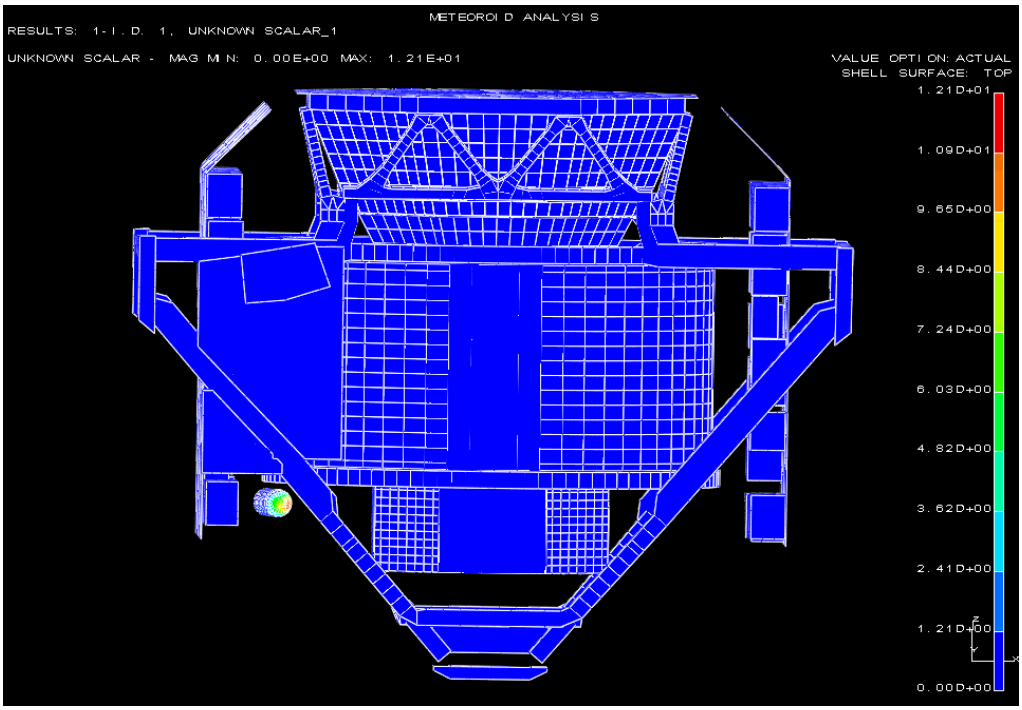

Figure 2: Warm Helium Tank

Critical parameters for all three tanks are summarized in Table 1. Note that the MDPs described in the table are for flight operations. These are based on thermal profiles which are more extreme than what will be reached on the ground, so their use here is conservative.

Table 1: Summary of AMS-02 Tank Pressure Characteristics

Tank	Arde' Part No.	MOP	MDP	Proof Pressure	Burst Pressure
Xenon	D4815	2500 psid	3000 psid	4500 psid (1.5xMDP) (1.8xMOP)	9300 psid (3.1xMDP) (3.7xMOP)
CO_2	D4816	1440 psid	3200 psid	4800 psid (1.5xMDP) (3.3xMOP)	6400 psid (2.0xMDP) (4.4xMOP)
Helium	D4697	2900 psid	3538 psid	7250 psid (2.0xMDP) (2.5xMOP)	8845 psid (2.5xMDP) (3.0xMOP)

As can be seen in the table, each tank meets the relevant AIAA and NASA pressure requirements, usually with a large margin:

- All tanks have a burst factor of at least 2.0, exceeding the requirement of 1.5 in ANSI/AIAA S-081 para 4.2.2.
- All tanks have been proof tested to a minimum of 1.5xMDP, meeting the requirement in ANSI/AIAA S-081 para 5.1.2 and exceeding the requirement of 1.1xMDP in KNPR 8715.3 para 13.18.1d.
- All tanks have a burst pressure at least three times higher than the maximum operating pressure, which does not trigger the special tank handling requirements defined in KNPR 8715.3 paras 13.18.1e, f, and g.

Based on this, the AMS-02 COPVs clearly do not present any abnormal safety hazard so long as the composite overwrap does not sustain damage and proper handling procedures are followed.

Mitigation Plan

There are four credible avenues for mechanical damage to the AMS-02 COPVs:

1) Damage during tank construction and assembly.
2) Incidental contact during shipping and/or storage.
3) Incidental contact by personnel or tools during nearby assembly operations.
4) Falling objects dropped from above.

The first cause can be eliminated from further consideration given that the tanks were fully inspected and certified by Arde'. Each tank has an associated Acceptance Data Package which documents the tank inspections and the proof pressure testing for each unit. In all cases, the

tank met the requirements of both ANSI/AIAA paragraph 5.1 and KNPR 8715.3 paragraph 13.18.1.

Control of the remaining hazards implies the presence of protective covers of some type both above the tanks and between the tanks and surrounding work areas. Shielding must not only encompass the final payload configuration, but also during the assembly process where special care and operations are in place to eliminate damage risk to the tanks. Addressing this requires a review of the planned life history of each tank after it left Arde'.

Helium Tank (D4697)
The helium tank was sent from Arde' to Scientific Magnetics (SM), the AMS-02 magnet contractor, in a foam-lined crate. The tank will remain in its crate in a storage location physically separated from the magnet assembly area until it is ready for installation. At that point, it will be installed concurrently with its surrounding rigid MMOD shielding. Once installed, this shielding will also serve as incidental damage protection. Therefore the only period when the composite surface is exposed to contact will be during the installation itself which will occur with special handling procedures in place. The composite will be clearly identified as a no-contact area, and no other work will be allowed to take place on the VC while this operation is underway. For similar reasons, scaffolding above the assembly area will be closed to personnel, cleared of loose items and no crane operations will be allowed in proximity. All of these requirements will be clearly documented in the assembly procedures and will be enforced by project and quality support.

Xenon Tank (D4815) and Carbon Dioxide Tank (D4816)
The xenon and carbon dioxide tanks were delivered to the Massachusetts Institute of Technology (MIT), the contractor for the specific detector which uses the gas supplies. For mission success reasons, MIT then applied heaters and thermostatic control devices to the outside surface of the COPV. This procedure was developed by MIT and reviewed by Arde'. The installation itself was done by MIT technicians with Arde' QA present. After installation, the entire tank surface (with the obvious exception of the areas now underneath the heaters) was reinspected and the proof pressure test was redone. This process went smoothly and no anomalies were noted.

Once the heaters were installed, protective covers were installed over the composite surface of each tank. These covers will remain in place through all tank assembly and installation operations, except on the rare occasions when direct access to the tanks themselves is required. There are two occasions on which this will be required:

1) The covers were removed to allow installation of the interior tank MLI blankets. This installation was done by trained NASA personnel who were made aware of the delicate nature of the tank surfaces. The tank assembly itself was in its shipping fixture during this operation, physically separated from the rest of the hardware, and

access was restricted to the two technicians doing the work and the quality engineer providing oversight. No scaffolding was nearby, and no crane operations were allowed until the covers were replaced on top of the new blankets.

2) The covers and the MLI will be removed later to allow potting of the thermostats previously installed on the COPV surface. This operation will be done by the same technicians as in the previous step, the tank assembly will be in the same fixture as before, and identical access and crane restrictions will be included in the procedure.

Even after the tank assembly is installed, the protective covers will remain in place until the outermost layer of MLI is ready to be installed. At that point, the covers will be removed. A temporary shield will be installed above the tanks to prevent damage from items falling above. In addition, the MMOD shield should be installed on the outboard side of the tanks shortly afterwards. Just as with the helium tank, this MMOD shield will also serve as a protective cover for work taking place on that side of the tanks. At this point, only minimal work will remain in the area adjacent to the inboard side of the tanks, so the betacloth layer in the MLI combined with clear instructions on assembly procedures will be sufficient to protect the tanks from damage from inadvertent contact.

The temporary shield protecting the inboard side of the xenon and carbon dioxide tanks will remain in place during all remaining assembly and testing operations until AMS-02 reaches the launch pad with the exception of the thermal-vacuum test and the electromagnetic interference test. In both of these cases, the payload will be in the controlled environment of the test chambers and no personnel will be present. The risk of falling debris will be controlled by standard procedures at the test site. Once the tests are complete, the temporary shield will be reinstalled prior to any activity taking place near the tanks. These requirements will be clearly documented in the test procedures.

Final removal of the temporary shield will take place at the launch pad just prior to final installation in the bay. As with the test operations, this is a controlled environment and the risk of falling debris and inadvertent contact will be controlled by standard KSC procedures. Additionally, since both tanks are on the aft side of AMS-02, the payload itself will provide some layer of protection precluding falling debris from having an unobstructed path to the composite surfaces.

In summary, the risk of damage to each of the three COPVs used in AMS-02 has been mitigated through a combination of shielding and procedural controls. All inspection data, analysis, and procedures will be fully documented in the ground safety package. Based on this, the risk of COPV rupture due to impact damage to the overwrap is considered fully controlled.